RESEARCH REGARDING THE GENETIC POTENTIAL TO PRODUCE POLLEN OF THE PARENTAL FORMS OF MAIZE HYBRIDS

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ABSTRACT

Knowledge about flowering biology presents a special importance for the process of maize hybrid seed multiplication, especially when the tassel flowering of paternal forms does not coincide with the stigma appearance at maternal ones. Under these circumstances, it is necessary to know certain specific parameters of flowering dynamics, such as: duration of tassel flowering of paternal forms, days in which the tassels release maximum of pollen and the number of days in which the stigma manifests receptivity for pollen and ensure, from this viewpoint, the cross fertilization. The researches performed in 2002 at A.R.D.S. Teleorman on flowering biology of paternal forms of some maize single crosses recently registered, refer to the quantitative aspect of flowering dynamics, especially flowering duration, average pollen quantity released by a tassel during flowering and its repartition on days.

Key words: maize flowering biology, genetic potential, pollen quantity

INTRODUCTION

In order to obtain high seed yields in crossing fields, a special importance presents the knowledge of different aspects of maize flowering biology, especially when there is no coincidence between flowering and silking of parental forms. The achievement of a good fertilization is directly conditioned by the tassel flowering of paternal forms and silking of maternal ones, under optimum temperature and humidity conditions. Under these conditions, the achievement of genetic and physiological compatibility between pollen and stigma and the coincidence between flowering and silking, are essential for hybrid seed multiplication.

With a view to better know the different aspects of maize flowering biology, studies, observations and experimental researches were performed abroad (Russell et al., 1963; Fleming et al., 1964; Cohran and Russell, 1966) as well as in Romania (Andronescu, 1915; Craciun, 1955; Diaconu, 1963; Covor et al., 1963; Sarca et al., 1977). The experimental results from Romania and abroad, emphasize the fact that, the moment of tassel appearance, flowering duration, released pollen quantity, its viability and stigma receptivity are dependent on the genotype – environment interaction (Sarca et al., 1978). Fleming et al. (1964) and Sarca et al. (1976) appreciate that maize inbreds specifically react under the climatic conditions influence, as regards the pollen releasing.

Ghertuskii (1962) emphasized the influence of high air temperature, associated with atmospherical drought, on maize tassel flowering characteristics. Also, Sidorov (1957), established the optimum temperature for pollen releasing at 22-25°C, under conditions of an enough humid atmosphere. Under very high temperature conditions (over 35°C) and dry air, the pollen vitality significantly diminishes. The pollen viability duration varies depending on both environmental conditions and genotype (Andronescu, 1915).

The maize inbreds present a reduced adaptation ability as compared to hybrids (Cabulea, 1962). Because there are frequent situations in which there is no coincidence between tassel flowering and parental form silking, it is very important to know the main aspects of maize flowering dynamics: tassel flowering duration and days in which the paternal forms release the maximum quantity of pollen and the duration of maximum receptivity of stigma.

Under this aspect, researches which had in view the tassel flowering duration, average pollen quantity released by a plant and its distribution, on days, were initiated forty years ago in Romania (Diaconu, 1963).

The researches performed in 2002, at A.R.D.S. Teleorman on maize flowering biology had in view to restart and continue the study and observation of parental form behaviour during flowering, regarding the flowering dynamics,

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achievement of flowering coincidence, by the investigation of answer reaction of plant biology during flowering depending on the climatic conditions variation.

MATERIAL AND METHODS

The results and their interpretation were processed after the model proposed by Diaconu (1963). As research material, 9 maize inbreds, parental forms for 11 single crosses production, were used. The experiments were performed under A.R.D.S. Teleorman conditions, in 2002, year characterized by hydric deficit during the first vegetation period (emergence-intensive growth) and by hydric excess during the other vegetation stages (flowering-cross fertilization-grain filling and formation).

The inbreds LC-403, LC-408, LC-411, LC-435, LC-544, LC-607, LC-646, LC-686, LC-700, paternal forms of some registered single crosses, were tested.

Each inbred was sown on two rows of 50 plants per row. In order to determine the pollen quantity, 5 plants from each variant were isolated. The isolated plants were gently tilted to the adjacent row, with a view to avoid the pollen losses by shaking. The pollen, daily harvested from each plant, was sifted, dried and weighed by analytical scale, during flowering. For the numerical determination of tassel flower elements (spikelets, flowers, stamens), three tassels from each variant (inbred) were harvested. The number of pollen grains at a stamen and on an average at a tassel (plant) was determined by counting under microscope the pollen grains from three stamens at each plant.

PLANT DEVELOPMENT CONDITIONS

1. Soil conditions

The experiments were placed on a cambic-vertic chernozem, with a loamy-cleyey texture, with a beginning of clay-illuvial-vertic/pseudogleyey degradation process, having the following physic-chemical features:

- clay content: 45-45.5%;
- aeration porosity: 5.7-9.1%;
- compaction degree: 9.4-17.4%;
- humus content: 3.4-3.6%;
- pH: 5.9-6.1;
- nitrogen content: IN = 3.6;
- mobile phosphorus content: 36-40 ppm;
- mobile potassium content: 220-260 ppm;
- water field capacity: 1,882 m^3/ha;
- wilting point: 997 m^3/ha.

2. Climatic conditions of experimentation

From the analysis of rainfall during April-September 2002, a quantity of 435.2 mm was registered, exceeding with 110.3 mm the multiannual average for this period of maize biological cycle (fig. 1). This rainfall, more abundant than the normal, had an un-uniform distribution, characterized by an unequal repartition from one month to another and even from one decade to another.

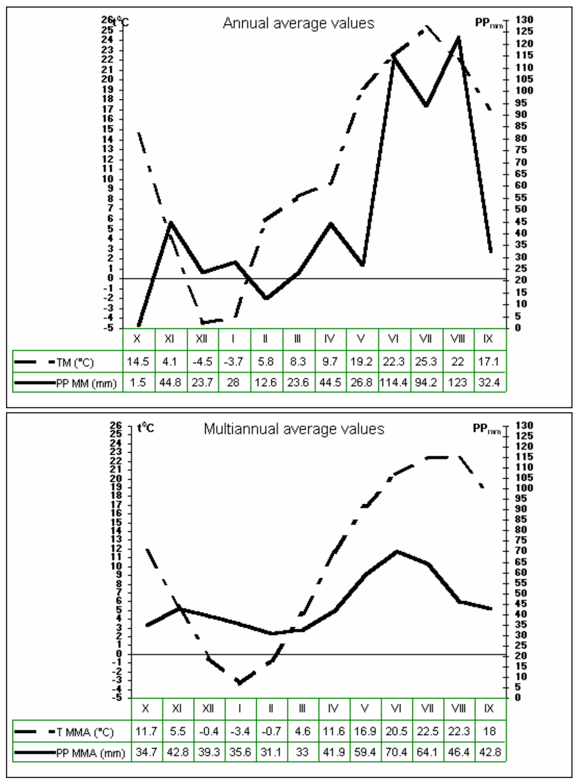

Figure 1. Climatic condition (October 2001-September 2002) at A.R.D.S. Teleorman

Thus, in comparison with the multi-annual monthly average, the rainfall was in a deficit in May (-32.6 mm) and September (-10.4 mm), which coincided with maize emergence and 2-4 leaves development stage, physiological and harvesting maturity respectively.

Values of rainfall over the monthly normal were registered in June (+44.0 mm), July (+30.1 mm) and August (+76.6 mm), during maize intensive growth, tasselling and silking, pollination and grain filling and formation.

The hydric deficit registered in May led to a certain stress at the level of metabolic function of young emerged plants, determining a diminution of their growth. The more reduced rainfall from September did not influence the maize biology. The abundant rainfall registered during June-August 2002, was useful for maize. The rainfall during summer came on a background of a soil minimum water reserve in spring due to the accentuated deficit of rainfall in comparison with normal, registered during October 2001-March 2002, of -82.2 mm and which led to a climatic stress from the first vegetation period.

Under thermic aspect, during April-September 2002 the air temperature had monthly average values inferior to normal, in April (-1.9°C), August (-0.3°C) and September (-0.9°C) and exceeded the multiannual normal values in May (+2.3°C), June (+1.8°C) and July (2.8°C).

The warm days from May positively contributed to the plant growth, even if the rhythm was slowed down by the soil hydric deficit due to insufficient rainfall.

The high temperatures from June and July together with abundant rainfall positively influenced the vigorous growth, tasselling-silking and pollination-cross fertilization, but created a warm and wet climate which encouraged the attack of some specific diseases and pests (*Helminthosporium turcicum, Ustilago maydis, Giberella zeae, Fusarium moniliforme, Ostrinia nubilalis, Heliothis armigera).*

Under dry land conditions, the increased temperatures registered on the background of abundant rainfall offered to maize many warming and wet days both in air and soil. Under these conditions, only on about one third of period, the aridity index exceeded the normal values and encouraged the heat during short time (2-3 days), which alternated with intervals less torrid, in which the increased humidity diminished the negative influence of high daily temperatures, limiting in this way the heat manifestation and its impact on plants.

In conclusion, under climatic aspect, the agricultural year 2001-2002 could be considered as having two distinct parts: first (October 2001-March 2002) characterized as very poor in rainfall, arid, with a high soil hydric deficit, with negative influence on maize growth and emergence during the first vegetation stages; second (April-September 2002) with rainfall and temperatures over average, which balanced the previous deficits.

RESULTS AND DISCUSSION

The experimental results show that quantitatively, the potential to produce pollen by the tested paternal lines, expressed by pollen quantity (dried at U = 6-9%) released on an average by a plant, varies between 1,310 mg at LC-408 and 1,730 mg at LC-700 (Table 1).

The paternal line flowering was generally quite uniform, the variability ranging between 9.0 and 12%. The LC-408 and LC-411 lines manifested the greatest uniformity at flowering with a variation coefficient of 9.91% and 9.46% respectively. The LC-403, LC-435, LC-646 and LC-607 lines manifested a good uniformity at flower-

Table 1. Pollen quantity released by a plant during flowering, at maize paternal inbreds
A.R.D.S. Teleorman, 2002

Inbreds	Pollen quantity (mg)*			
	X	S^2	S	S%
LC - 700	1730	41737.5	± 204.3	11.81
LC - 403	1625	27850.0	± 166.88	10.27
LC - 607	1560	29326.5	± 171.35	10.98
LC - 646	1520	25312.5	± 159.10	10.47
LC - 686	1480	29387.5	± 171.43	11.58
LC - 544	1420	25987.5	± 161.21	11.35
LC - 411	1390	17287.5	± 131.48	9.46
LC - 435	1355	19512.5	± 139.69	10.31
LC - 408	1310	16862.5	± 129.86	9.91

n = 5
* dry pollen (U = 6 - 9 %)

ing with a variation coefficient of 10.27 and 10.98%. The LC-544, LC-686 and LC-700 lines manifested a moderate uniformity at flowering with a variation coefficient of 11.35 and 11.81%. There is a positive correlation between the pollen quantities released by paternal inbreds during flowering and the number of spikelets from tassel. This correlation is no more completely evident regarding the ratio between the number of spikelets and the number of pollen grains released by them, which demonstrates that among the inbred lines with an equal number of floral elements in panicle (spikelets, flowers, stamens), there are differences regarding the pollen abundance in stamens (their genetic potential to produce pollen) (Table 2).

The analysis of flowering duration at the tested inbreds shows its framing between 5.6 and 8.8 days, which means a quite reduced variation interval, demonstrating a certain homogeneity of these lines (Table 3). Thus, a reason to sustain this opinion is the quite restricted amplitude of the manifested variability regarding the aspect of pollen releasing, which ranged between 7.21% (great uniformity of flowering duration at LC-411) and 12.31% (middle uniformity at LC-686 and LC-408).

Based on the analysis of pollen release duration, on days, it was established that, at all tested inbreds, the pollen releasing was ununiform. The greatest pollen quantity was released in an interval of 3-6 days (Table 4). Thus, the maximum quantity of pollen was released in first, second, third, fourth and fifth days of flowering at LC-686, LC-403 and LC-646; in second, third, fourth, fifth, sixth and seventh days of flowering at LC-700; in second, third, fourth, fifth and sixth days of flowering at LC-544; in second, third, fourth and fifth days of flowering at LC-435 and LC-607; in third, fourth, fifth and sixth days of flowering at LC-411 and in third, fourth and fifth days of flow-

Table 2. Average number of spikelets, flowers, stamens and pollen grains per plant, at paternal inbreds
A.R.D.S. Teleorman, 2002

Inbreds	Spikelets	Flowers	Stamens	Pollen grain at a stamen	Total pollen grains per plant
	X ± Sx	X	X	X ± Sx	X
LC -700	1129 ± 177	2258	6774	3314 ± 14	22,449,036
LC - 403	960 ± 103	1920	5760	3461 ± 72	19,935,360
LC - 607	899 ± 42	1798	5394	3154 ± 65	17,012,676
LC - 646	863 ± 142	1726	5178	3584 ± 31	18,557,962
LC - 686	801 ± 11	1602	4806	3124 ± 27	15,013,944
LC - 544	746 ± 63	1492	4476	3262 ± 42	14,600,712
LC - 411	725 ± 28	1450	4350	2958 ± 34	12,867,300
LC - 435	494 ± 61	988	2964	3229 ± 117	9,570,756
LC - 408	474 ± 33	948	2844	3516 ± 14	9,999,504

n = 3

Table 3. Tassel flowering duration (in days) of paternal inbreds of maize hybrids
A.R.D.S. Teleorman, 2002

Inbred	Tassel flowering duration (days)				
	X	S^2	S	S%	Sx
LC - 700	8.2	0.7	0.84	10.20	± 0.37
LC - 403	7.4	0.3	0.55	7.41	± 0.24
LC - 607	6.4	0.3	0.55	8.56	± 0.24
LC - 646	6.6	0.3	0.55	8.30	± 0.24
LC - 686	6.8	0.7	0.84	12.31	± 0.37
LC - 544	7.2	0.7	0.84	11.63	± 0.37
LC - 411	7.6	0.3	0.55	7.21	± 0.24
LC - 435	5.6	0.3	0.55	9.79	± 0.24
LC - 408	8.8	0.7	0.84	12.31	± 0.37

n = 5

ering at LC-408 (Figures 2 and 3).

Since the pollen release exceeds an interval of 2-3 days, the tested paternal inbreds proved to have a good pollination potential, being recommended for development of hybrids in crossing fields from the south of the country.

Table 4. Daily pollen quantity released by maize paternal inbreds
A.R.D.S. Teleorman, 2002

Variants	Inbreds	Plants (rep.)	Total pollen mg	Of which, on days								
				D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
V_2	LC - 686	P_1	1,540	290	290	500	425	30	5	0	0	0
		P_2	1,490	340	380	360	245	150	10	5	0	0
		P_3	1,565	220	505	415	325	50	40	10	0	0
		P_4	1,185	230	335	240	170	150	45	10	5	0
		P_5	1,620	65	165	760	465	150	15	0	0	0
		x	**1,480**	**229**	**335**	**455**	**326**	**106**	**23**	**5**	**1**	**0**
V_6	LC - 403	P_1	1,815	280	270	415	215	100	75	10	0	0
		P_2	1,710	130	390	435	415	190	130	15	5	0
		P_3	1,690	135	380	600	290	205	60	20	0	0
		P_4	1,400	40	290	310	415	215	100	20	10	0
		P_5	1,510	45	100	610	395	275	75	10	0	0
		x	**1,625**	**126**	**376**	**474**	**346**	**197**	**88**	**15**	**3**	**0**
V_{10}	LC - 700	P_1	1,940	235	440	600	300	210	105	50	0	0
		P_2	1,700	70	270	285	335	450	110	100	70	10
		P_3	1,880	40	80	185	360	430	560	195	25	5
		P_4	1,415	40	75	245	360	395	150	140	10	0
		P_5	1,715	45	80	150	220	790	215	190	25	0
		x	**1,730**	**86**	**189**	**293**	**315**	**455**	**228**	**135**	**26**	**3**
V_{12}	LC - 411	P_1	1,530	80	110	465	610	230	30	5	0	0
		P_2	1,485	15	60	450	555	310	80	10	5	0
		P_3	1,210	5	10	140	480	325	210	30	10	0
		P_4	1,420	25	50	140	445	400	270	90	0	0
		P_5	1,305	20	30	85	510	375	240	40	5	0
		x	**1,390**	**29**	**52**	**256**	**520**	**328**	**166**	**35**	**4**	**0**
V_{14}	LC - 646	P_1	1,570	105	135	350	635	240	100	5	0	0
		P_2	1,610	135	205	460	695	65	40	10	0	0
		P_3	1,675	290	460	590	240	90	5	0	0	0
		P_4	1,265	90	300	605	150	105	15	0	0	0
		P_5	1,480	110	405	550	255	125	30	5	0	0
		x	**1,520**	**146**	**301**	**511**	**395**	**125**	**38**	**4**	**0**	**0**
V_{16}	LC - 544	P_1	1,385	70	130	330	445	390	15	5	0	0
		P_2	1,460	15	85	425	635	170	130	0	0	0
		P_3	1,570	5	5	10	665	430	285	160	10	0
		P_4	1,160	10	70	265	340	345	100	25	5	0
		P_5	1,525	20	180	215	410	535	100	65	0	0
		x	**1,420**	**24**	**94**	**249**	**499**	**374**	**126**	**51**	**3**	**0**
V_{18}	LC - 435	P_1	1,490	40	290	455	495	210	0	0	0	0
		P_2	1,395	5	45	435	735	170	5	0	0	0
		P_3	1,465	20	320	585	320	215	5	0	0	0
		P_4	1,265	45	655	295	180	90	0	0	0	0
		P_5	1,160	75	120	230	440	285	10	0	0	0
		x	**1,355**	**37**	**286**	**400**	**434**	**194**	**4**	**0**	**0**	**0**
V_{20}	LC - 408	P_1	1,375	5	15	265	840	220	30	0	0	0
		P_2	1,440	80	100	115	935	135	55	20	0	0
		P_3	1,285	10	50	200	770	215	35	5	0	0
		P_4	1,350	120	210	255	740	15	10	0	0	0
		P_5	1,100	5	55	180	660	115	60	20	5	0
		x	**1,310**	**44**	**86**	**203**	**789**	**140**	**38**	**9**	**1**	**0**
V_{22}	LC - 607	P_1	1,710	0	20	145	1015	265	255	10	0	0
		P_2	1,675	15	505	565	580	5	5	0	0	0
		P_3	1,620	70	95	365	760	255	60	15	0	0
		P_4	1,510	70	185	490	560	190	15	0	0	0
		P_5	1,285	0	5	450	625	180	25	0	0	0
		x	**1,560**	**31**	**162**	**403**	**708**	**170**	**72**	**5**	**0**	**0**

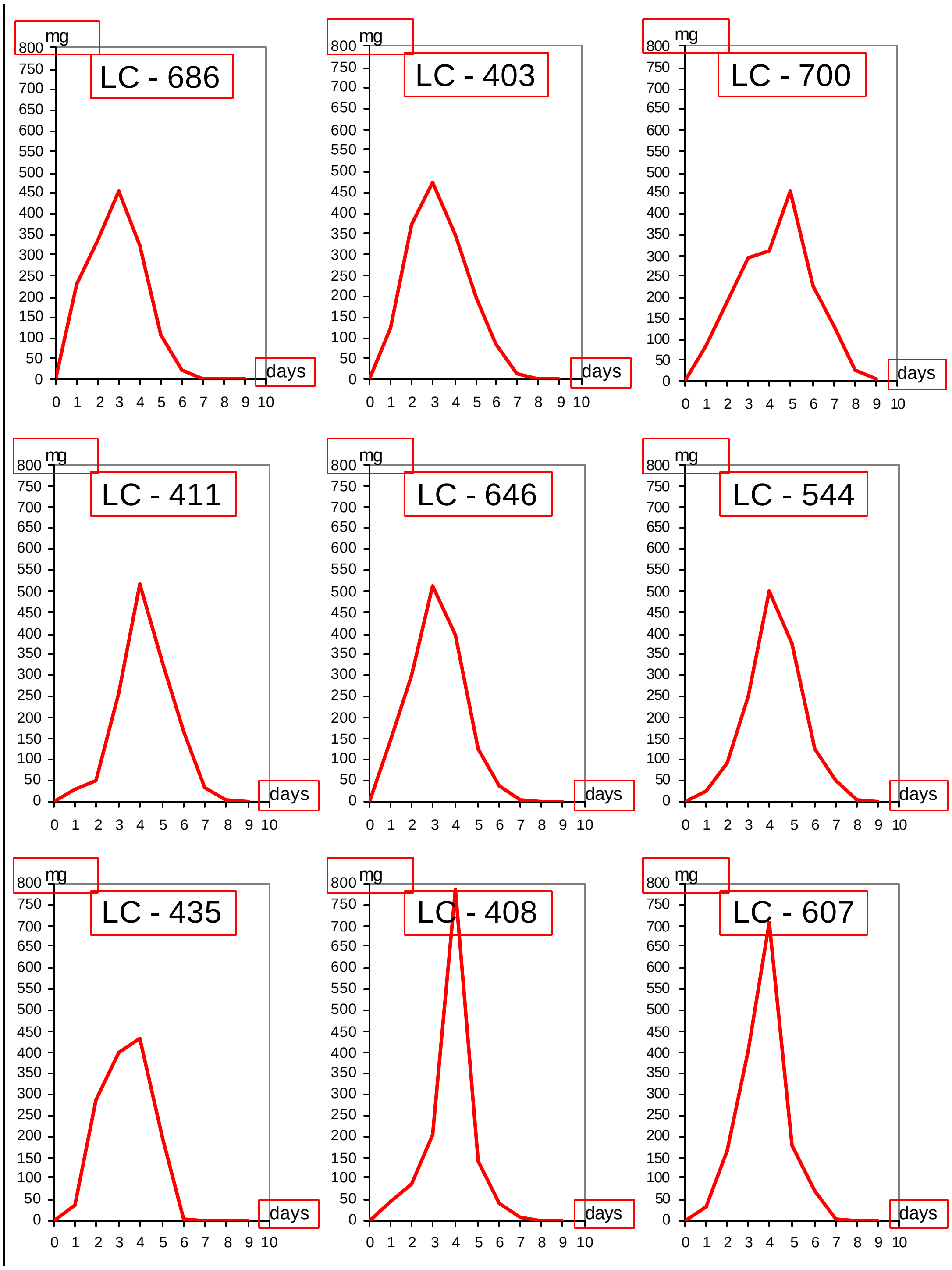

Figure 2. Dynamics of pollen releasing during flowering at paternal forms, large-scale representation A.R.D.S. Teleorman, 2002

Because, under climatic conditions of 2002 year, the flowering took place at daily high temperatures, but on the background of a very favourable hydric regime, the pollen releasing was practically total.

The microscopic analyses performed immediately after flowering showed that in the stamens of the tested inbreds did not remain pollen immobilized into pollinic sacks.

The results presented in table 5, show that the average weight of a pollen grain is of

0.0001011 mg = 1.011 x10^{-4}, with a variability amplitude between 0.0000771 and 0.0001416 mg. Under compact crop conditions, in parental forms multiplication fields, at a density of 45,000 plants/ha, the paternal tested inbreds ensure a pollen quantity that ranges between 59 and 78 kg/ha (dry pollen at U= 6-9%), releasing between 9 and 22 million pollen grain per plant. Taking into account, on an average 500-600 ovules per maternal form, in a cross fertilization plot with maternal/paternal ratio of 3:1, each ovule could contain 5,000-6,000 till 12,000-14,000 pollen grains, sufficient quantity for pollination.

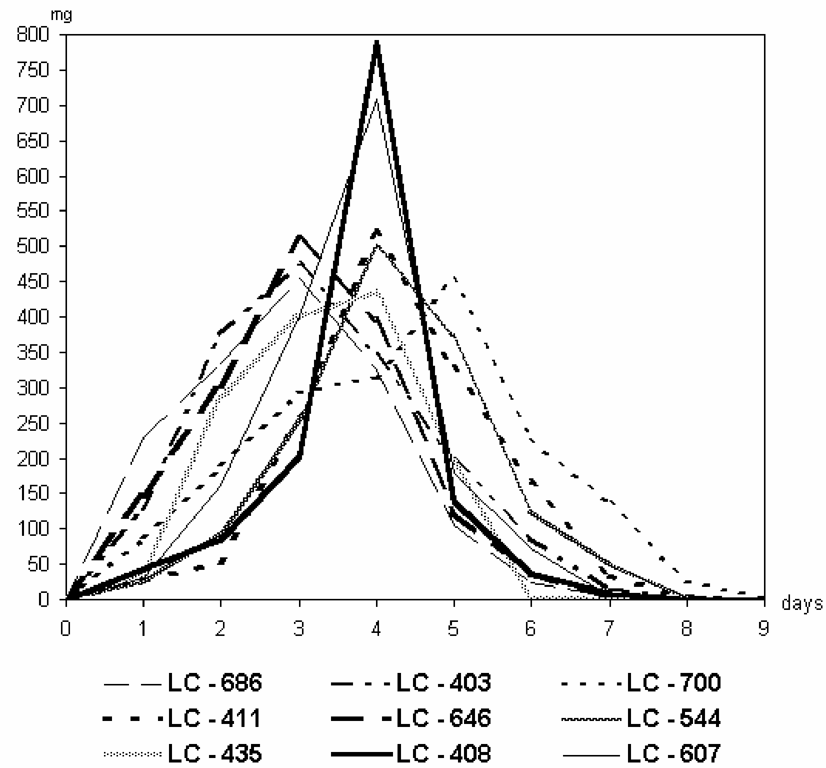

Figure 3 . Dynamics of pollen releasing during flowering of the maize inbreds, paternal forms, superposed representation
A.R.D.S. Teleorman, 2002

Table 5. Total pollen quantity released by a tassel and the weight of a pollen grain at maize inbreds, paternal forms
A.R.D.S. Teleorman, 2002

Inbreds	Total pollen quantity released by a tassel (X) mg	Total number of pollen grain at a tassel (X) no	Weight of a pollen grain*	
			mg	abbreviated expression
LC - 700	1,730	22,449,036	0.0000771	7.71 x 10^{-5}
LC - 403	1,625	19,935,360	0.0000815	8.15 x 10^{-5}
LC - 607	1,560	17,012,676	0.0000917	9.17 x 10^{-5}
LC - 646	1,520	18,557,962	0.0000819	8.19 x 10^{-5}
LC - 686	1,480	15,013,944	0.0000986	9.86 x 10^{-5}
LC - 544	1,420	14,600,712	0.0000973	9.73 x 10^{-5}
LC - 411	1,390	12,867,300	0.0001080	1.08 x 10^{-4}
LC - 435	1,355	9,570,756	0.0001416	1.42 x 10^{-4}
LC - 408	1,310	9,999,504	0.0001310	1.31 x 10^{-4}

* dry pollen (U = 6 - 9 %)

CONCLUSIONS

The genetic potential of the investigated inbred lines to produce pollen makes possible the achievement of a good pollination, the amplitude of pollen emission per tassel ranging between 1,310 mg (LC-408) and 1,730 mg (LC-700).

From the pollen-producing potential viewpoint, the inbreds are characterized by uniformity, the variation coefficient (s%) ranging between 9.46% (LC-411) and 11.81% (LC-700).

The flowering duration is of 5-8 days, the lines presenting a good uniformity, the variation coefficient (s %) ranging between 7.2% and 12.3%. The pollen is released in an interval of 2-5 days, between the second and the seventh days from flowering, fact which indicates a good pollination potential. A plant releases on an average 9-22 million pollen grains, amounting to each ovule of maternal form 5,000-14,000 pollen grains which lead to a good pollination and cross fertilization. The weight of a dry pollen grain (U = 6-9%) was about of 1.011 x 10^{-4} m.

The knowledge of peculiarities of paternal form flowering biology presents a great scientific and practical importance for the maize seed multiplication. The knowledge of these peculiarities leads to the:

- establishment of optimum sowing ratio between maternal and paternal lines, in cross fertilization plots;
- obtainment of a high grain yield percent and achievement of simultaneity between paternal form flowering and maternal ones silking.

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Table 1

Average yield of experiments with winter wheat cultivars, under irrigation and dry-land in six localities from the South of Romania (2002)

Locality	Average yield under: irrigation (kg/ha)	Average yield under: dry-land (kg/ha)	Yield percentage diminution
Caracal	8560	5601	34.6
Marculesti	4716	3075	34.8
Teleorman	5963	3594	39.8
V. Traian	6941	3794	45.3
Fundulea	4858	1918	60.5
Simnic	(8560)	380	95.6

Table 2

Percentage diminution of some plant features under water stress conditions as compared to irrigation

Locality	Plant number	Plant height	Grain filling period	Spike number	Grain/ear	TKW	Test weight
Caracal	0	14,9	15,0	7,9	10,2	14,1	0,9
Teleorman	0	10,0	19,2	12,0	12,0	11,9	1,0
V.Traian	34,9	21,0	16,9	42,5	12,2	2,9	8,1
Fundulea	4,9	28,8	24,9	6,9	28,9	29,5	3,9
Simnic	27,6	61,7	30,0	65,0	64,5	53,1	10,7
Media	13,5	27,3	21,2	26,9	25,6	22,3	4,9

Table 3

Minimum, maximum and average yields registered at Fundulea in 2002 in international trials WWEERYT with genotypes grouped depending on the originating country

Source	Average yield of the tested genotypes (kg/ha)	Maximum yield of the tested genotypes (kg/ha)	Minimum yield of the tested genotypes (kg/ha)
Romania	2368	2953	2073
Russia	2327	2453	1980
Ukraina-Odessa	2224	3013	1287
Hungary	2181	2780	1320
Ukraina-Mironovka	2108	2753	1500
Moldova	1927	2560	1293
Bulgaria	1898	2873	1313
Turkey	1893	2420	1487
Azerbaidjan	1460	1553	1367
Kazahstan	1422	1833	853
LSD 5%	243	275	

Table 4

Correlations between yield under water stress conditions and different traits

Locality	Average yield diminution because of water stress (%)	Correlation coefficients between yield under water stress conditions and:						
		yield under irrigation	plant height under stress conditions	plant height under irrigation	heading time	spike/ m²	grain/ear	TKW
Caracal	34,6	**0,48**	0,29	-0,31	-0,12	0,20	0,11	-0,30
Teleorman	39,8	**0,80**	0,35	0,31	**-0,85**	**0,58**	-	-
Valu Traian	45,3	0,04	0,33	0,20	**-0,40**	**0,42**	**0,40**	0,22
Fundulea	60,5	0,00	**0,46**	-0,31	**-0,46**	**0,52**	0,30	-0,17
Simnic	95,6	-0,01	**0,41**	**-0,62**	-0,04	**0,40**	**0,50**	0,15

The bold characters are significant at the probability level of 0.05

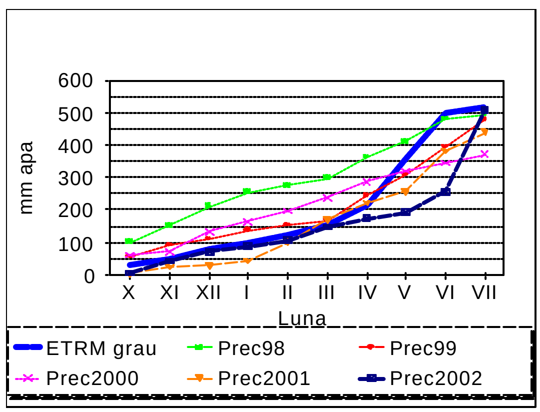

Figure 1. Average evapotranspiration and rainfall during 1999-2002 at Fundulea (mm water; month; wheat evapotranspiration; rainfall)

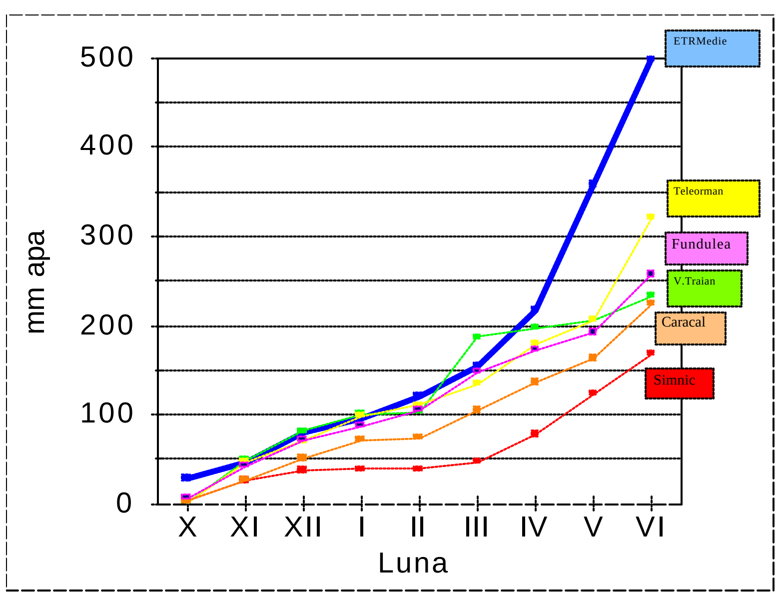

Figure 2. Average evapotranspiration and rainfall during the vegetation period in six locations of Southern of Romania in 2001-2002 year (mm water; month).

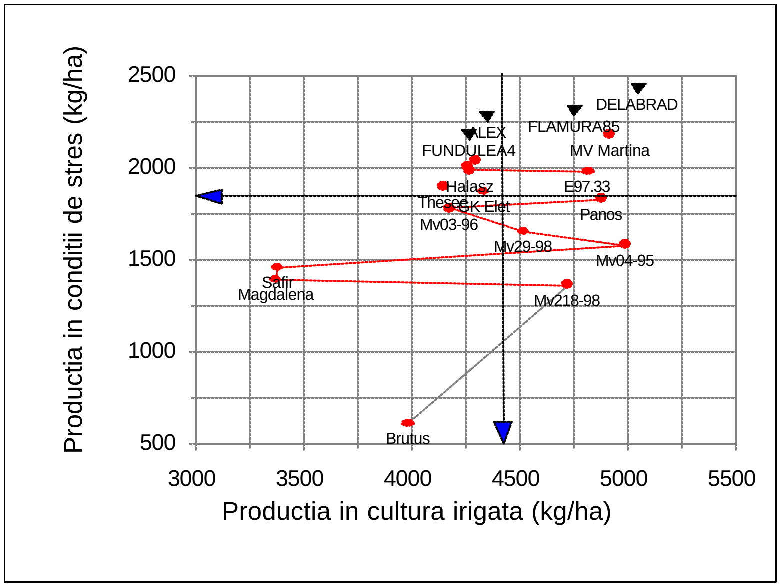

Figure 3. Yield obtained by some Romanian and foreign cultivars under irrigation and non-irrigation, in 2002 at Fundulea (arrows indicate the experiments average yield)(Yield under stress conditions; yield under irrigation).

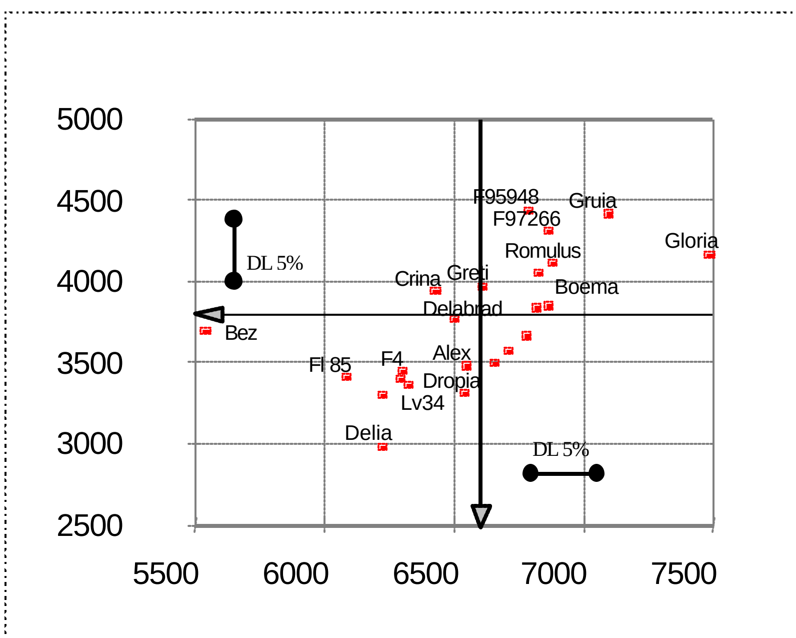

Figure 4. Average yields in four locations, obtained in 2002 by Romanian new lines and cultivars under irrigation and non-irrigation (arrows indicate experiments average yield)(Yield under non-irrigation; Yield under irrigation; LSD).